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Learning styles of science and engineering students in problem and project based education

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Abstract

At the Faculty of Engineering and Science at Aalborg University, Denmark, process skills are an integrated part of the curriculum objectives. During the first year programme, a special course in Collaboration, Learning and Project Management (CLP) is given to develop those skills. In order to develop students' learning and the CLP-course, the Felder-Soloman Index of Learning Styles (ILS®) has been used in that course and data has been collected to investigate whether some learning style preferences are more conspicuous than others in a problem based learning environment. The results show, more pronounced than similar studies, that the first year engineering students at Aalborg University are considerable more active than reflective. This results leads to a discussion of whether reflection and conceptualization should be facilitated further in the curriculum to balance the students learning style and more importantly enhance critical thinking on the actions taken.

Keywords: PBL, learning style preference, active learning.

1. INTRODUCTION

At Aalborg University, there is more than 30 years of experience in educating engineers in a problem and project based learning environment. The freshman year at Aalborg University is in many ways unique as it is explicitly emphasized in the curriculum that the students have to be able to contextualize the technical solutions and furthermore document that they have obtained process skills in order to manage a problem and team based project.

A compulsory course titled Cooperation, Learning and Project Management (CLP) has been established to facilitate the students' learning of process skills in connection with a PBL curriculum. The course includes theories and methods in the areas of co-operation, learning and project management and supports the students' work in writing a process analysis attached to their project report. The objective of this specific process analysis is for the students to develop awareness of the work and learning processes, in order to become better team learners and team workers [1,2]. The idea behind the process analysis was to stress the importance of structured reflection [3,4]; however, students did not react positively to this idea [2]. Several teachers found that the students had problems when they were confronted with assignments posed to facilitate reflection, giving the expression that the students were far more active than reflective.

In facilitating the students to contextualise the technical problems the teachers had similar experiences. A course named Technology, Humanity and Society (THS) has been offered to provide engineering students with an understanding of the interplay between the pure technical discipline and the context in which the technical solutions are to be implemented. Among those contextual factors are the rather comprehensive matters of resource exploitation, social responsibility, political processes and cultural adaptation. The course Technology, Humanity and Society is together with team supervision supporting the students in making a problem analysis to outline the overall demands to a technical solution, and a technological assessment after a given solution has been sketch out. However, staff found it very hard to get the students to reflect on the problem before getting into a technical solution, and this especially showed to be the case for the more traditional engineering professions.

We wished to investigate whether it could be validated that our students, and especially students from traditional engineering professions, which had a preference for active and not reflective learning could be validated through learning style tests. Furthermore, we wished to compare these results with similar investigations of engineering learning style preferences, as we found it possible that a PBL environment as the one at Aalborg University especially would attract active learners, which would increase the challenge of facilitation reflection even further. In order to investigate these aspects, data from The Felder-Soloman Index of Learning Styles (ILS®) was collected systematically. In the following we will give a short introduction to ILS® and the methodological framework, and we proceed by presenting our findings of using the ILS® among first year science and engineering students.

2. LEARNING STYLE INDICATORS IN EDUCATIONAL RESEARCH

Learning style is a concept derived from psychology. It normally refers to an individual's preference for operating in one way over another, so in that sense learning style tests point to the preferred ways of perceiving and processing information, whatever the task or the teacher [5]. Felder & Brent [6] define learning styles as characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment. Learning styles do not encompass the ability to learn. Abilities refer to how well you are doing things – and there might not always be a correlation between style and ability [5].

Besides serving as a personal tool for self-reflection, learning style tests have found their way into educational research, and here the main interest has been to investigate the correlation between learning styles and other characteristics, as for example grades [7-9]; choice of profession [7,10,11]; preferred carrier environment [9]; or demographic variables as gender [7,9-12]; ethnicity and parental social class [7,13]. In these investigations there is less focus on the individual score and more focus on creating a group-based learning style profile.

The Myers-Briggs Type Indicator (MBTI) [14] and Kolb's Learning Style Inventory (LSI) [15] have, together with the Felder-Soloman Index of Learning Styles (ILS®) dominated the studies of engineering learning styles [6]. The ILS®, the MBTI and the LSI are all inspired by Carl Jung's theory of psychological types, see [16,17]. This theory works with pairs of functional types which mutually exclude each other. For the learning style test, this means that the scores are always presented in a relative manner, as a balance between two complementary variables.

The ILS® consists of four complementary types to address how information is perceived and processed [18-20]:

- *Sensing versus intuition.* Sensors prefer sights, sounds and physical sensations, whereas the intuitive types prefer theoretical insights.

- *Active versus reflective.* Active types prefer learning by doing through interaction with the external world, whereas the reflective type prefers introspection.
- *Visual versus verbal.* Visual types prefer iconic codes such as pictures, whereas the verbal types prefer linguistic codes including both the spoken and written word.
- *Sequential versus global.* Sequential types prefer to learn using continuous steps and linear reasoning processes, whereas global types prefer to learn using a system-oriented manner relating seemingly unconnected fragments and they finally “get it”.

An overview of the characteristics of the four complementary sets of concepts is presented in table 1.

Complementary learning styles	
<i>Sensing</i> - Draws on physical sensation - Practical and observing - Prefer the concrete: facts and data - Prefer repetition	<i>Intuitive</i> - Draws on insight - Imaginative and interpretive - Prefer the abstract: theory and modelling - Prefer variation
<i>Visual</i> - 'Show me how' - Prefer pictures and diagrams	<i>Verbal</i> - 'Tell me how' - Prefer written and spoken explanations
<i>Active</i> - 'Let's try it out' - Process information by physical activity - Learn by working with others	<i>Reflective</i> - 'Let's think it through' - Process information introspectively - Learn by working alone or in pairs
<i>Sequential</i> - Understand in continual and incremental steps - Linear reasoning process - Convergent thinking and analysis	<i>Global</i> - Understand in large leaps - Tacit reasoning process - System thinking and synthesis

TABLE 1. Characteristics for the four dimensions in the ILS® [18-20].

3. THE METHODOLOGICAL FRAMEWORK

The reliability and validity of the ILS® has been discussed and investigated in several studies [7, 11, 21-22]. The reliability and validity of the ILS® is and should be a matter for discussion and further research. As noted by Felder and Henriques [23], the learning style categories are by no means comprehensive, the dimensions of the ILS® has not shown to be fully independent and the preferred learning style may not be the style that enables the students to learn most effectively. However, the ILS® has been widely used for showing a tendency of a dominant learning style preference within a given group of students. Zywno [21] supports construct validity of the ILS® by showing no significant difference between consecutive years of the ILS® scores collected from a consecutive cohort of engineering students, and by referring to other studies [7, 12, 24, 25-27] of engineering learning styles showing the same overall style distribution. Furthermore, Zywno [21] argues that discriminant validity of the ILS® is supported by a number of studies [7, 28-29] showing significant differences in scores for populations with different characteristics, e.g. engineering students compared to business students [7].

In this study the ILS® has been distributed to first year program at the Faculty of Engineering and Science, Aalborg University from the following professions: Architecture and Design, Building and Civil Engineering, Computer Science, Computer Engineering, Electronics, Physics, Geography, Global Business Development, Industry, Informatics, Chemistry & Bio-technology, Land Surveying, Mathematics, Nanotechnology, Planning & Environment, Software and Health Technology. In the fall of 2003 this data-collection was systematized within all sectors, and data was collected from 493 students.

To be able to compare the learning styles of engineers and science at Aalborg University with similar research results, the average means and standard deviations have been calculated. Felder & Brent [6] gathered results from 17 sources, but other references have also provided comparable research results on engineering learning preference [7, 10, 11, 21, 30]. Furthermore, the distribution of strong (+/- 11-9), moderate (+/- 7-5) and mild preferences (+/- 3-1) have been calculated to illustrate the balance of the difference scales. To investigate differences between engineering students from different sectors, two-way analyses of variance (inter-scale correlation) have been conducted based on the learning tests as dependent variables and education as independent variables.

4. FINDINGS

The 493 first year engineering students in 2003 were characterized by a majority of active, visual, sensor types, while the number of sequential and global learners was relatively equal. If we look at the strength of the learning style preferences illustrated in table 2, we found that only the sequential/global learning styles could be considered as balanced. The number of moderate and strong preferences was three times higher for active learners than for reflective learners, and there was around twice as many strong and moderate sensors as intuitive learners. Most remarkably, more than half of the cohort (315) were strong or moderate visual learners.

	<i>Strong (-)</i>	<i>Moderate (-)</i>	<i>Mild (-)</i>	<i>Mild (+)</i>	<i>Moderate (+)</i>	<i>Strong (+)</i>
<i>Active(-)/Reflective(+)</i>	68	137	157	84	42	5
<i>Sensitive(-)/Intuitive(+)</i>	38	126	154	98	53	24
<i>Visual (-)/Verbal (+)</i>	118	197	112	55	10	1
<i>Sequential(-)/Global(+)</i>	5	70	144	177	81	16

TABLE 2. The learning styles of the 493 students divided into strong, moderate and mild preferences.

These results correspond to the assumption initially made by Felder & Silverman [18] describing many or most engineering students as visual, sensing and active, and some of the most creative students as global learners. However, differences in the balance of learning style can be found when comparing the ILS® scores collected at Aalborg University, Denmark, and ILS® scores from other studies, see table 3. In table 3, the average results of the 493 ILS®-scores for this study are shown together with similar results from 2506 ILS® scores of engineering students presented by Felder & Brent [6].

No considerable differences are seen in regard to the sensing/intuitive and visual/verbal dimensions. Engineers are in average dominated by a visual preference, as 4 out of 5 prefer visual representations. But students at Aalborg University seem to be considerable more global than the average for the 2506 engineering students. Actually, this result represents the lowest percentage of sequential learners compared with the reported learning style preferences for students, summarized by Felder & Brent [6]. One possible explanation of this difference is that a considerable part of the population (16 percent) is related to Architecture and Design, which is not traditionally considered as an engineering profession. In this group the students are significantly more global, as we will elaborate on in the following section.

<i>Populations</i>	<i>A (%)</i>	<i>S(%)</i>	<i>Vs(%)</i>	<i>Sq(%)</i>	<i>Reference</i>
Aalborg University (N=493)	73	65	87	44	This study
Average of studies below (N=2506)	64	63	82	60	[6]
Iowa State (N=129)	63	67	85	58	[31]
Michigan Tech. (N=83)	56	63	74	53	[32]
Ryerson University (N=338)	59	65	88	62	[33] [34] [21]
Students 2000 (N=87)	53	66	86	72	
Students 2001 (N=119)	60	66	89	59	
Students 2002 (N=132)	63	63	89	58	
Tulane (N=437)	59	54	86	52	[24] [35]
Second-year students (N=245)	62	60	88	48	
First Year Students (N=192)	56	46	83	56	
Univ. of Western Ontario (N=858)	69	59	80	67	[12]
First Year students (N=499)	66	59	78	69	
Fourth Year Students (N=359)	72	58	81	63	
University of Limerick (N=167)	70	78	91	58	[36]
University of Michigan (N=143)	67	57	69	71	[25]
University of São Paulo (N=351)	60	74	79	50	[27]

TABLE 3. Engineering student average results from 493 ILS®-scores collected at Aalborg University, Denmark and the 2506 ILS® scores presented by Felder & Brent [6].

Furthermore, table 3 shows that engineering students at Aalborg University are considerably more active than their fellow students. Together with British students at Oxford University, with a very limited population studied (n=21), this result represents the highest percentage of active learners compared to the reported learning style preferences for students summarized by Felder & Brent [6]. This is also the case compared with the investigations of Kovačić [30] and Fowler et al [10] with a preference for the active learning style at 50 and 58 percent respectively. By comparing the mean and standard deviation from this investigation to results in Litzinger et al [11], it can likewise be concluded that the ILS® scores for the engineering students at Aalborg University are more oriented towards an active learning style (mean 2.7 in comparison to 0.02).

Table 4 illustrates the means of the different groupings in regard to the four scales: active/reflective, sensing/intuition, visual/verbal and sequential/global.

<i>Profession</i>	<i>Active %</i>	<i>Sensing %</i>	<i>Visual %</i>	<i>Sequential %</i>
Architecture & Design (N=77)	79	38	96	32
Building & Civil Engineering (N=63)	84	81	95	60
Computer Engineering & Science (N=70)	71	69	81	47
Physics & Nanotechnology (N=25)	80	52	92	28
Electronics (N=57)	72	74	88	40
Mathematics (N=14)	50	71	79	57
Global Business Development & Industry (N=73)	78	55	85	68
Chemistry, Bio- & Health Technology (N=62)	53	77	77	52
Geography, Land Surveying and Planning & Environment (N=52)	77	71	81	44

TABLE 4. Learning style preferences related to disciplines at Aalborg University.

All sectors at the Faculty of Engineering and Science, Aalborg University are in average *active*, with the one exception of students who specialize in math, but even in this case the distribution of active and reflective learners are close to equal. Of the engineering professions Chemistry, Bio- and Health-technology ($p < 0.03$) deviate significantly by being more reflective.

Besides Physics and Nanotechnology, average engineering and science students at Aalborg University are sensors. However, Architecture and Design ($p < 0.012$), Physics and Nanotechnology ($p < 0.035$) and Global Business Development and Industry ($p < 0.017$) are all deviating significantly by being more intuitive.

The average learning style within Building and Civil Engineering, Mathematics and Chemistry, Bio- and Health Technology was sequential, but as mentioned earlier the average engineering student at Aalborg University is more global. Architecture and Design ($p < 0.033$), Physics and Nanotechnology ($p < 0.020$), Global Business Development and Industry ($p < 0.009$) and Geography, Land Surveying, Planning and Environment ($p < 0.039$) are all deviating significantly by being more global.

The *visual* types are in the majority, predominantly in the sector of Architecture and Design, where 74 out of 77 students were visual learners. Industry and Global Business Development ($p < 0.009$), Electronics ($p < 0.024$), Building and Civil Engineering ($p < 0.014$) and Architecture and Design ($p < 0.004$) are all deviating significantly by being more visual.

5. CONCLUDING REMARKS

The overall profile of the engineering student learning preference is similar to several other studies showing that engineering students are active, sensing and visual, whereas the sequential tendency is more balanced. Due to the very broad range of disciplines taught at the Faculty of Science and Technology at Aalborg University, our data also shows examples of diverse learning styles among the different categories within engineering and science. Engineering students are not just one cohort with similar learning patterns. For example, students in the area of Chemistry, Bio- and Health Technology were significantly more reflective than their fellow students.

When the data from Aalborg University is compared with data from other institutions, we can conclude that engineering students at Aalborg University, besides students of Chemistry, Bio- and Health Technology, seemed to be even more active in their learning style. This result has underlined the need of finding new ways to motivate and facilitate reflection among students with a dominant active learning style. Some incentives have been taken besides the more traditional ways of inductive teaching e.g. by organise lectures as workshops or using the ILS® to raise awareness of the different learning styles and reflect on team communication. However, more systematic research is needed to facilitate a balance between active experimentation and reflection.

There is no doubt that the experiment is an important element in developing creativity – but to prevent creativity skills from turning into elusive ideas without any kind of implementation, the students have to learn to jump from common-sense ideas to more substantiated ideas based on practical experience and theoretical reflection – after all that what's engineering is all about. Reflection is a precondition for problem-based learning, for setting up methodological frameworks, for being innovative and, on the meta-cognitive level, for being able to systematically improve individual and organisational learning processes.

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